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PATENT SPECIFICATION



Application Date: April 26, 1922. No. 11,727/22.

199,879

Complete Left: Jan. 26, 1923.

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PROVISIONAL SPECIFICATION.

Improvements in or relating to Induction Coils.

We, THE BRITISH LIGHTING AND IGNITION COMPANY, LIMITED, of B.L.I.C. Works, Cheston Road, Aston, Birmingham, a British company, and ERNEST OWEN TURNER, of 35, Mayfield Road, Moseley, Birmingham, a subject of the King of Great Britain, do hereby declare the nature of this invention to be as follows:—

10 This invention relates to induction coils and has particular reference to ignition coils intended for use with internal combustion engines.

Hitherto induction coils have been made with open magnetic circuits, that is to say, the magnetic circuit associated with the windings of the coil was composed partly of iron and partly of air. As the reluctance of the air part of the magnetic flux path is so much greater than that of the iron, the magneto-motive force of the primary windings is spent almost entirely in overcoming the reluctance of the air gap. In the various forms of induction coils heretofore employed, although the air path has been made of various lengths, in all cases the length has been greatly in excess of that required, as will be hereinafter explained, for obtaining in the most economical and advantageous manner a given output from the apparatus.

With ignition coils, and especially in the case of those which are intended to operate with high speed internal combustion engines having a large number of cylinders, for example 6, 8 or more cylinders, the intervals of time which can be allowed for the current to rise in the primary winding prior to its being interrupted is extremely short, and in many cases the current is interrupted at a value which is only a small fraction of the value of the current when the interruptions take place at a low speed, so that the energy available in the second-

ary circuit is lowered. The rate of rise of current in an inductive circuit is governed by the time constant or the ratio of the inductance to the resistance of the circuit, which may be represented by the expression

$$\frac{\text{Flux X Turns}}{\text{Voltage.}}$$

Assuming therefore no alteration of the flux to take place, and that the voltage and current consumption of the coil are allowed to remain the same, a great reduction of the length of the air path, or in other words a replacement of this part of the path by iron, will lead to a great reduction in the number of ampere turns required and therefore a considerably fewer number of turns in the primary winding will be required. The effect of this is to bring about a greatly reduced time constant, and thereby to overcome the difficulty referred to above in providing a coil which will give an adequate performance when used with high speed engines. For example, with a certain size of coil having its secondary winding positioned intermediate between the iron core and the primary winding, a flux of 10,000 lines was produced by 1300 ampere turns; in a coil of the same design but having its air gap reduced to the lowest limit (as will be hereinafter referred to, the same flux was obtained with 200 ampere turns. The time constant of the coil was thus reduced to less than one-sixth of its former value. As in many cases so great a reduction in the time constant is unnecessary for overcoming the difficulty in operating at high speeds referred to above, the factor of 6, or whatever figure this may amount to, may be advantageously employed in other ways. For example, instead of the turns being reduced to one-sixth they

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may be halved, the flux doubled and the extra turns available used in overcoming the increased reluctance of the extended iron circuit.

5 It will generally be found that the best performance of the coil is not obtained merely by the provision of a single air gap placed at random in the magnetic circuit. A better performance
10 may frequently be obtained by splitting up the total length of air gap required into two or three separate air gaps at different positions in series in the magnetic circuit. We have also found that
15 certain positions in the magnetic circuit give more favourable results than others; for example if the primary winding consists of a simple coil over which the secondary is wound, it is advantageous if
20 one air gap be made in the very middle of the coil, that is to say, at an equal distance from either end of the layers of the primary winding, and other gaps be then made, as, for instance, at each
25 end of the core, thus providing, in this case, at least three gaps in the circuit. These gaps may be made equal in length, or the respective lengths of the gaps may be so arranged as to give the best performance
30 of the coil as found by experiment. The performance of the coil is furthermore affected by the way in which the gap is made, by the direction of lamination of the iron on either side of the gap,
35 and by the amount of flux which leaves the iron in the neighbourhood and on both sides of the gap, thus forming a fringe. In designing the gaps in the magnetic circuit, particular care must be
40 taken that the flux path does not form itself in a plane at right angles to the plane of lamination of the iron, as the resultant eddy currents which are formed at the opening of the primary circuit
45 greatly reduce the benefit which can be gained by a reduction in the air gap length. Various forms of construction in accordance with the invention are hereinafter described, whereby the flux path in
50 the neighbourhood of the joints is designed so as to approach as nearly as possible to the ideal, that is to a path wholly confined to the direction of the laminations. Amongst the advantages
55 arising through the reduction in the air path of the magnetic circuit in accordance with the present invention are the following:

60 1. The time constant can be halved or decreased to some still greater proportion.

2. The number of secondary turns, in consequence of the increase of flux, may be halved or altered in some other proportion; this brings about a very considerable saving of space in the apparatus,

at the same time reducing the cost of material and labour.

3. As a result of the increased saturation of the iron, the performance of the coil with a varying voltage applied to the primary winding is rendered more uniform.

4. Another advantage which may be derived dependent on the foregoing, is that with the saturation density of the iron being approached and the performance being more nearly uniform, the generation of a higher sparking voltage from whatever cause, such as greatly increased primary voltage, increased spark gap length, or disconnection in the external high tension circuit, is prevented, and consequently the safety gap most usually provided on ignition coils may be dispensed with.

5. The magnet circuit being almost a closed one there is practically no field external to the coil, which consequently may be enclosed in an almost closely fitting tube of brass, iron, or other metal, which need not be slotted in the direction of the flux path to prevent excessive eddy-currents, as is commonly the case with coils having an open magnetic circuit as heretofore employed.

6. It has been found that a much smaller condenser is necessary to suppress sparking at the contact breaker, and this again effects a substantial saving in cost especially if a mica condenser be employed.

7. The mutual inductance of the windings is increased thus enabling still fewer secondary turns to be employed.

The present invention comprises an induction coil in which the flux path for almost the whole of the magnetic circuit is of iron or other magnetic material, the dimensions of the air gap or gaps left in the circuit being relatively small but of a size sufficient to ensure a low value for the idle flux and quick demagnetisation when the primary current is broken. If no air gap at all were provided the flux would fall, at the opening of the contact-breaker points, to a value equal to the product of the remanence of the steel and its cross sectional area; in such a case the resulting flux drop, on which the value of the secondary voltage produced depends, might only amount to 50 per cent. of the total flux associated with the windings, or even less. By the provision however of an air gap or gaps in the circuit, the flux falls to a lower value, the air gap or gaps helping to de-magnetize the iron. If sufficient air gaps be left to reduce the magnetism to a comparatively small fraction of the working value of the flux,

it can be assumed that the entire coercive force of the steel is effective in maintaining the flux in the air gaps, and consequently the product of the coercive force of the steel and the mean length of the magnetic circuit is approximately equal to the product of the sum of the lengths of the air gaps and the average flux density in the said gaps after the primary circuit has been opened. From the above considerations it will be seen that suitable dimensions of the air gap or gaps can readily be determined, the chief factors being the amount of inactive flux which is best permitted, the length of the magnetic circuit, and the coercive force of the iron. For example with a coil having 300 turns, a magnetic circuit of length 10 centimetres and a total flux of 15,000 lines, (the coercivity of the soft steel used being taken for the sake of example as 1.5, C.G.S. units) then assuming the inactive flux to be one-tenth of the total, the area of the air gap face (for a gap of one millimetre) or of each of the air gap faces (the sum of the individual gaps being one millimetre) would be about 10 square centimetres and the number of ampere turns absorbed by the air gap or gaps would be approximately 120, the balance of 180 out of the total 300 turns being required for the iron parts of the circuit.

We have found in practice that the best performance is not always given with air gaps determined by the above considerations, but that a greater total length of air gap or gaps may be required; the difference is to be accounted for largely by the insufficient lamination of the circuit, and in particular to the ineffectiveness of the laminations in the neighbourhood of the joints, to which reference has already been made. The degree of closeness of the air gap length determined by the above theoretical considerations to which this value may be approached in practice to obtain the best result is a measure of the success in laminating the circuit.

As examples of coils having their magnetic circuits arranged in accordance with the present invention, the following forms of construction may be instanced. The core, over which the primary and secondary windings are wound, may be provided with lateral iron extension pieces projecting slightly beyond the outermost winding, so that the core and extension pieces present an **H**-shape appearance, taking a longitudinal section through the coil. The magnetic circuit is completed by iron members which are arranged so as nearly to close the top and bottom portions of the **H**, and

an air gap or gaps may be left between the lateral extension pieces which form the side members of the **H** and the core, in the core as already described, or elsewhere, in accordance with the extent of the air space it is desired to leave in the magnetic circuit. In a modification of this mode of construction an air gap or gaps may be provided between one or both ends of the core and the lateral extension pieces, and the top and bottom portions of the **H** may be completely closed by iron junction pieces, or two of the air gaps may be formed around the core, where it passes at each end through the lateral extension pieces. In another modification the core may be provided with extension pieces which enclose either the top or bottom half of the coil alone, one or more air gaps being left where desired in the magnetic circuit constituted by the core and its extension pieces.

In order to ensure that the flux at each joint shall pass as much as possible in the plane of the laminations, various forms of construction may be adopted. For example, when the mechanical construction is such that it is necessary to make a break in the magnetic circuit but it is not desired to introduce an air gap at that spot the iron laminations at the junction of the members may be interleaved with one another. Where flux is to be carried from one direction to another at right angles the edges of the laminations in the two planes may be bevelled so as to make a joint similar to that in the corners of a picture frame. Another method which may also be employed where the joint to be made between planes of laminations at an angle to each other is to bend portions of one set of laminations more nearly into the plane of the other set, so that the flux being conveyed to this portion of the laminations is conveyed across the gap into the adjoining laminations without being constrained to leave the plane of the laminations. Still another method may be adapted, as, for example, at the joint between the core and the extension pieces when the latter are broader than the width of the core; a hole may be formed in the extension pieces, through which the core may be introduced and the air gaps between core and extension pieces so arranged that the flux is constrained to pass from the one to the other across only the edges of the laminations.

In all the modes of construction above described, the primary winding may be wound over the core, and the secondary winding over the primary, or the windings may be reversed in position; alter-

natively there may be two cores, a portion or the whole of each winding being wound over each core. The section of the core may be of any desired shape, and may be made up of flat laminations, or of wire, square, or round in section, whilst the extension pieces forming the remainder of the magnetic circuit may be made up of laminations rivetted or otherwise held together. Means may also be provided for obtaining a very definite and exact extent of air gap or gaps, in a manner well suited to commercial manufacture, by introducing non-magnetic material of a definite thickness into the air gap or gaps left in the magnetic circuit. Slots or openings may of course be provided where necessary, to reduce eddy current losses, in the usual manner. Further the magnetic circuit may be so screwed as to eliminate any leakage or fringing magnetic fields outside the active structure of the coil, which may be enclosed in a relatively closely-fitting metal case of brass, iron, or other material, which may be constructed without joints or slits in the direction of the flux path or at right angles to the direction of the windings.

Dated this 26th day of April, 1922.

HASELTINE, LAKE & Co.,
28, Southampton Buildings, London,
England, and
Park Row Building, 15, Park Row, New
York, N.Y., U.S.A.
Agents for the Applicants.

COMPLETE SPECIFICATION.

Improvements in or relating to Induction Coils.

We, THE BRITISH LIGHTING AND IGNITION COMPANY, LIMITED, of B.L.I.C. Works, Cheston Road, Aston, Birmingham, a British company, and ERNEST OWEN TURNER, of 35, Mayfield Road, Moseley, Birmingham, a subject of the King of Great Britain, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to induction coils and has particular reference to ignition coils intended for use with internal combustion engines.

Hitherto induction coils have been made with open or partially closed magnetic circuits, that is to say, the magnetic circuit associated with the windings of the coil was composed partly of iron and partly of air. As the reluctance of the air part of the magnetic flux path is so much greater than that of the iron, the magneto-motive force of the primary windings is spent almost entirely in overcoming the reluctance of the air gap. In the various forms of induction coils hereinbefore employed the air path has been made of various lengths and even with coils in which it has been proposed to construct the armature so as to increase considerably the usual ratio between the lengths of the iron and air paths with the object of improving the closing of the magnetic circuit, the length of the air path left has still been greatly in excess of that required, as will be hereinafter explained, for obtaining in the most

economical and advantageous manner a given output from the apparatus.

The present invention comprises an induction coil with primary and secondary windings and a magnetic circuit or circuits linked with the said windings in which the flux path for almost the whole of the magnetic circuit or circuits is of iron or other magnetic material, the dimensions of the air gap or gaps left in the circuit being relatively small but of a size sufficient to ensure a low value for the idle flux and quick demagnetisation when the primary current is broken.

With ignition coils, and especially in the case of those which are intended to operate with high speed internal combustion engines having a large number of cylinders, for example 6, 8 or more cylinders, the interval of time which can be allowed for the current to rise in the primary winding prior to its being interrupted is extremely short, and in many cases the current is interrupted at a value which is only a small fraction of the value of the current when the interruptions take place at a low speed, so that the energy available in the secondary circuit is lowered. The rate of rise of current in an inductive circuit is governed by the time constant or the ratio of the inductance to the resistance of the circuit, which may be represented by the expression

$$\frac{\text{Flux} \times \text{Turns}}{\text{Voltage.}}$$

Assuming therefore no alteration of the flux to take place, and that the voltage and current consumption of the coil are allowed to remain the same, a

great reduction of the length of the air path, or in other words a replacement of this part of the path by iron, as is adopted with induction coils constructed in accordance with the present invention, will lead to a great reduction in the number of ampere turns required and therefore a considerably fewer number of turns in the primary winding will be required. The effect of this is to bring about a greatly reduced time constant, and thereby to overcome the difficulty referred to above in providing a coil which will give an adequate performance when used with high speed engines. For example, with a certain size of coil of the type in which the secondary winding is positioned intermediate between the iron core and the primary winding, and having an open magnetic circuit with an air path of considerable length as has heretofore been usual, a flux of 10,000 lines was produced by 1300 ampere turns; in a coil of the same design but having its air gap reduced to the lowest limit (as will be hereinafter referred to), the same flux was obtained with 200 ampere turns. The time constant of the coil was thus reduced to less than one-sixth of its former value. As in many cases so great a reduction in the time constant is unnecessary for overcoming the difficulty in operating at high speeds referred to above, the factor of 6, or whatever figure this may amount to, may be advantageously employed in other ways. For example, instead of the turns being reduced to one-sixth they may be halved, the flux doubled and the extra turns available used in overcoming the increased reluctance of the extended iron circuit.

It will generally be found that the best performance of the coil is not obtained merely by the provision of a single air gap placed at random in the magnetic circuit. A better performance may frequently be obtained by splitting up the total length of air gap required into two or three separate air gaps at different positions in series in the magnetic circuit. We have also found that certain positions in the magnetic circuit give more favourable results than others; for example if the primary winding consists of a simple coil over which the secondary is wound, it is advantageous if one air gap be made in the very middle of the coil, that is to say, at an equal distance from either end of the layers of the primary winding and other gaps be then made, as, for instance, at each end of the core, thus providing, in this case, at least three gaps in the circuit. These gaps may be made equal in length, or the

respective lengths of the gaps may be so arranged as to give the best performance of the coil as found by experiment. The performance of the coil is furthermore affected by the way in which the gap is made, by the direction of lamination of the iron on either side of the gap, and by the amount of flux which leaves the iron in the neighbourhood and on both sides of the gap, thus forming a fringe. In designing the gaps in the magnetic circuit, particular care must be taken that the flux path does not form itself in a plane at right angles to the plane of lamination of the iron, as the resultant eddy currents which are formed at the opening of the primary circuit greatly reduce the benefit which can be gained by a reduction in the air gap length. Various forms of construction in accordance with the invention are hereinafter described, whereby the flux path in the neighbourhood of the joints is designed so as to approach as nearly as possible to the ideal, that is to a path wholly confined to the direction of the laminations. Amongst the advantages arising through the large reduction in the air path of the magnetic circuit in accordance with the present invention are the following:—

1. The time constant can be halved or decreased to some still greater proportion.

2. The number of secondary turns, in consequence of the increase of flux, may be halved or altered in some other proportion; this brings about a very considerable saving of space in the apparatus, at the same time reducing the cost of material and labour.

3. As a result of the increased saturation of the iron, the performance of the coil with a varying voltage applied to the primary winding is rendered more uniform.

4. Another advantage which may be derived dependent on the foregoing, is that with the saturation density of the iron being approached and the performance being more nearly uniform, the generation of a higher sparking voltage from whatever cause, such as greatly increased primary voltage, increased spark gap length, or disconnection in the external high tension circuit, is prevented, and consequently the safety gap most usually provided on ignition coils may be dispensed with.

5. The magnetic circuit being almost a closed one there is practically no field external to the coil, which consequently may be enclosed in an almost closely fitting tube of brass, iron, or other metal, which need not be slotted in the direction of the flux path to prevent excessive

eddy-currents, as is commonly the case with coils having an open magnetic circuit as heretofore employed.

6. The mutual inductance of the windings is increased thus enabling still fewer secondary turns to be employed.

In considering the factors governing the extent to which the air-gap may be reduced and the dimensions of the air gap or gaps, the effects resulting from a closed magnetic circuit will first be briefly discussed. If no air gap at all were provided the flux would fall, at the opening of the contact-breaker points, to a value equal to the product of the remanence of the steel and its cross sectional area; in such a case the resulting flux drop, on which the value of the secondary voltage produced depends, might only amount to 50 per cent. of the total flux associated with the windings, or even less. By the provision however of an air gap or gaps in the circuit, the flux falls to a lower value, the air gap or gaps helping to demagnetise the iron. If sufficient air gaps be left to reduce the magnetism to a comparatively small fraction of the working value of the flux, it can be assumed that the entire coercive force of the steel is effective in maintaining the flux in the air gaps, and consequently the product of the coercive force of the steel and the mean length of the magnetic circuit is approximately equal to the product of the sum of the lengths of the air gaps and the average flux density in the said gaps after the primary circuit has been opened. From the above considerations it will be seen that suitable dimensions of the air gap or gaps can readily be determined, the chief factors being the amount of inactive flux which is best permitted, the length of the magnetic circuit, and the coercive force of the iron. For example with a coil having 300 turns, a magnetic circuit of length 10 centimetres and a total flux of 15,000 lines (the coercivity of the soft steel used being taken for the sake of example as 1.5 C.G.S. units), then assuming the inactive flux to be one-tenth of the total, the area of the air gap face (for a gap of one millimetre) or of each of the air gap faces (the sum of the individual gaps being one millimetre) would be about 10 square centimetres and the number of ampere turns absorbed by the air gap or gaps would be approximately 120, the balance of 180 out of the total 300 turns being required for the iron parts of the circuit.

Further considerations governing the approximate length of air gap to be left in the circuit in order to secure the best performance in the case of induction coils

in accordance with the present invention are as follows:—If B represents the flux density (before the primary circuit is broken) at the face of an air gap, δ the sum of the length of all air gaps, H_c the coercive force of the iron, and L_i the length of iron path, then we have the approximate relation

$$\delta = \frac{H_c L_i}{p B}$$

where p represents whatever fraction of the value of B to which it is desired to reduce the flux at the interruption of the primary circuit. Assuming for example that the value of H_c is 1.5 and that p is 0.1, under these circumstances the best value of δ is chosen as 15 times the ratio of the length of iron circuit to the maximum flux density at the air gap face. It will readily be understood that this ratio may be varied considerably without departing from the principle of the invention. For example, the value of H_c may vary between 1 and 3, whereas the fraction p may be chosen between 0.05 and 0.4 with the result that the corresponding values of air gap may lie between 2.5 and 60 times the ratio of length of iron path to maximum flux density. It is not desirable to exceed this range much in either direction, as, for example, if p is made smaller the air gap is being lengthened at the cost of primary ampere-turns practically to no useful purpose, since the amount of extra demagnetisation effected is negligibly smaller, whereas if p is chosen greater than 0.4, the active flux becomes a very small portion of the (total) maximum flux.

We have found in practice that the best performance is not always given with air gaps the size of which exactly accords with the considerations mentioned above, but that a somewhat greater total length of air gap or gaps may be required than that corresponding to the calculated length; the difference is to be accounted for largely by the insufficient lamination of the circuit, and in particular to the ineffectiveness of the laminations in the neighbourhood of the joints, to which reference has already been made. The degree of closeness of the air gap length determined by the above theoretical considerations to which this value may be approached in practice to obtain the best result is a measure of the success in laminating the circuit.

In the accompanying drawings:—

Figures 1 to 6 illustrate examples of coils in diagrammatic longitudinal section with various modes of arrangements

of their magnetic circuits in accordance with the present invention,

Figure 7 illustrates a detail in connection with the construction shown in Figure 6, and

Figures 8, 9 and 10 illustrate various forms of joints in the magnetic circuit.

In Figure 1 *a* represents the core, *b* the primary winding, and *c* the secondary winding, the magnetic circuit being completed by the iron cheeks *d*, *d*¹ and the top and bottom iron members *f*, *f*¹. Small air gaps as shown are left at *e* or these may be left merely between the cheek *d* or *d*¹ and the members *f*, *f*¹, or merely between *f* or *f*¹ and the cheeks *d*, *d*¹, in accordance with the extent of the air space it is desired to leave in the magnetic circuit. The section of the members *f*, *f*¹ on the line A B at right angles to the axis of the core *a* may be circular, and the section of the core can be of any desired shape, the core being constructed of flat laminations or of wire of square or circular section.

In Figures 2 and 3 the constructions are generally similar to that of Figure 1, save that in the former (Figure 2) the air gaps *e* are located between the ends of the core *a* and the iron cheeks *d*, *d*¹, whilst in the latter (Figure 3) the air gap *e* is formed around the core where it passes through the cheeks *d*, *d*¹. In both cases an air gap at one end of the core only may be left if desired.

Figures 4 and 5 show two arrangements in which the magnetic circuits *a*, *d*, *a*¹, *d*¹ are constructed of iron laminations rivetted or otherwise held together; in Figure 4 two air gaps are provided as shown at *e*, whilst in Figure 5 there are two cores *a*, *a*¹ and one air gap at *e*.

In the upper part of Figure 6 there is shown in section a somewhat different construction of magnetic circuit, this consisting of the core *a*, and two cup shaped iron members *g*, *g*¹ one of which *g*¹ is made smaller in diameter than the other *g* so as to fit within it, the air gap being arranged as shown at *e*. Alternatively the two end cheeks attached to the core may be formed with fingers or arms *h* as indicated in Figure 7, the said fingers or arms being folded over towards the centre as indicated in the sectional elevation comprising the lower part of Figure 6, the air gaps therein being provided as shown in the upper part of this same figure.

In order to ensure that the flux at each joint shall pass as much as possible in the plane of the laminations, various forms of construction may be adopted. For example, when the mechanical construction is such that it is necessary to make

a break in the magnetic circuit but it is not desired to introduce an air gap at that spot the iron laminations at the junction of the members may be interleaved with one another. Where flux is to be carried from one direction to another at right angles the edges of the laminations in the two planes may be bevelled so as to make a joint similar to that in the corners of a picture frame as shown in Figure 8. A method which may be employed where the joint is to be made between planes of laminations at an angle to each other concomitantly with the introduction of an air gap is illustrated in Figure 9, where the portions of one set of laminations *k* are bent more nearly into the plane of the other set *l*, so that the flux is conveyed across the gap into the adjoining laminations without being constrained to leave the plane of the lamination; another method that may be adopted under somewhat similar circumstances as, for example, at the joint between the core and the extension pieces when the latter are broader than the width of the core is illustrated in Figure 10, where a hole *o* is formed in the extension piece *d* through which the core *a* is introduced. In this construction the air gap between the core *a* and the extension piece *d* is so arranged that the flux is constrained to pass from the one to the other across only the edges of the laminations.

In all the methods of construction of coils in accordance with this invention above described, the primary winding may be wound over the core, and the secondary winding over the primary, or the windings may be reversed in position. The section of the core may be of any desired shape, and may be made up of flat laminations, or of wire, square, or round in section, whilst the extension pieces forming the remainder of the magnetic circuit may be made up of laminations rivetted or otherwise held together. Means may also be provided for obtaining a very definite and exact extent of air gap or gaps, in a manner well suited to commercial manufacture, by introducing non-magnetic material of a definite thickness into the air gap or gaps left in the magnetic circuit. Slots or openings may of course be provided where necessary, to reduce eddy current losses, in the usual manner. Further the magnetic circuit may be so screened as to eliminate any leakage or fringing magnetic fields outside the active structure of the coil, which may be enclosed in a relatively closely-fitting metal case of brass, iron, or other material, which may be constructed without joints or slits in

the direction of the flux path or at right angles to the direction of the windings.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An induction coil comprising primary and secondary windings and a magnetic circuit or circuits linked with the said windings in which the flux path for almost the whole of the magnetic circuit or circuits is of iron or other magnetic material, the dimensions of the air gap or gaps left in the circuit being relatively small but of a size sufficient to ensure a low value for the idle flux and quick demagnetisation when the primary current is broken.

2. An induction coil comprising primary and secondary windings and a magnetic circuit or circuits linked with the said windings in which the flux path for almost the whole of the magnetic circuit or circuits is of iron or other magnetic material, the length of the air gap or the sum of the lengths of the air gaps left in the circuit amounting to from about 2.5 to 60 times the ratio of the length of the iron path to the maximum flux density at an air gap face before the primary circuit is broken.

3. An induction coil as claimed in Claim 1, in which iron of coercive force of about 1.5 C.G.S. units is employed for the magnetic circuit and the length of the air gap or the sum of the lengths of the air gaps left in the circuit amounts to about 15 times the ratio of the length of the iron path to the flux density at an air gap face before the primary circuit is broken.

4. An induction coil as claimed in Claim 1, 2 or 3 in which the air gap, or one of a plurality of air gaps, is located at about the middle of the iron core of the coil.

5. An induction coil as claimed in Claim 1, 2 or 3 in which three air gaps

in the magnetic circuit are provided, one of the said gaps at about the middle of the iron core of the coil, and the other gaps at each end respectively of the said core.

6. An induction coil as claimed in Claim 1, 2 or 3 in which the air gap or gaps is or are located between lateral cheeks or extension pieces of the core and the top and bottom members connecting together the said extension pieces, which members complete the magnetic circuit.

7. An induction coil as claimed in Claim 1, 2 or 3 having its magnetic circuit and air gap or gaps in the said circuit arranged substantially as described with reference to one or other of the constructions illustrated in Figures 1 to 6 of the accompanying drawings.

8. An induction coil as claimed in any of the preceding claims, in which the members forming the opposing faces of an air gap are arranged in such manner that the magnetic flux passes from one opposing face to the opposite one in the direction of the plane of the laminations of the material comprising the magnetic circuit.

9. An induction coil as claimed in any of the preceding claims, in which the coil is enclosed in a relatively closely fitting metal casing, for example of brass or iron, which casing is not slotted in the direction of the flux path.

10. An induction coil constructed, arranged and adapted to operate in accordance with one or other of the methods substantially as hereinbefore described with reference to the accompanying drawings for the purpose specified.

Dated this 26th day of January, 1923.

HASELTINE, LAKE & Co.,

28, Southampton Buildings, London, England, and

Park Row Building, 15, Park Row, New

York, N.Y., U.S.A.,

Agents for the Applicants.

[This Drawing is a reproduction of the Original on a reduced scale.]

